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Mechanized Excavation Work

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MECHANIZED EXCAVATION WORK

SINGLE-BUCKET EXCAVATOR OPERATIONS

The single-bucket excavators used in construction work (forward and reverse shovels, dragline and clamshell excavators) differ in design almost exclusively in the layout of their working gear. The types which have won the widest acceptance are the universal and semi-universal excavators with interchangeable working member. Excavators which have only one kind of working organ are in most cases machines of large size.

Single-bucket excavators can be equipped with various rigs, making it possible to use them as cranes, pile drivers for sinking poles, rammers, etc.

The main types of single-bucket excavators are the power shovel and the dragline excavator.

The latter is in particularly wide use in hydro-engineering construction.

In the construction of rural hydroelectric power plants, excavators having 0.25 cubic-meter scoops (where the volume of excavation is not less than 5,000 cubic meters) and 0.50 cubic-meter scoops (where the volume of excavation is not less than 10,000 cubic meters) are used, as well as excavators having 0.35 cubic-meter scoops. All excavators of the above type have interchangeable working gear.

Under rural hydroelectric power plant construction conditions where it is necessary to perform a large quantity of highly varied but small-volume work, a fully universal rig mounted on the S-80 tractor (SUTA-1) should find wide use.

Drawing 16. S-80 tractor with various types of interchangeable equipment (SUTA-1 rig).

In this rig an S-80 tractor is equipped with a hoist-and-traction winch and a sectional lattice-girder boom with interchangeable working gear for dragline, grab-bucket, crane, and ram.

Besides this gear, a bulldozer is hung on the front end of the tractor. The rig is remarkably mobile; its suspension gear can be assembled or taken down in 4 hours or less.

Depending on the type of working gear it carries, the rig can be used for the following construction operations: excavating various hollows, deepening and straightening river beds with the dragline excavator; digging deep foundation pits, deepening river bottoms, and loading loose material with the grab bucket; woods-clearing, levelling, and road work with the bulldozer; and sinking poles with the ram. With its suspension gear removed, the tractor can be used as a traction machine.

The rig has a covered trailer on which all the suspension gear and tools for repairing the rig are carried.

Let us now examine the operation of the different types of single-bucket excavators.

FORWARD-SHOVEL OPERATIONS

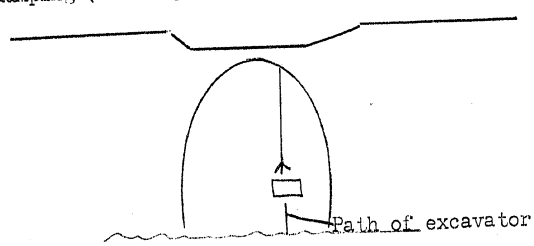
Forward-shovel working methods are determined first of all by the peculiarities in the design of the working gear of this type of shovel. These peculiarities comprise the relatively small radii of action of the forward shovel and the location of the excavator when operating below a face, as a result of which it is difficult to form a dump of any height at all.

Depending on the geometrical dimensions of the cross section of the cut, it can be worked in one or several passes of the excavator. The greater the area of the face to be worked with a single pass of the excavator, the greater the volume of earth excavated from a single station, the less it need move, and the less time is lost in movement. This is why one should try to work any cross section of a digging in the fewest possible passes of the excavator.

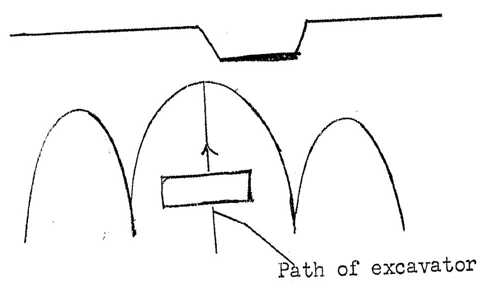
Drawing 17 shows the operating cycle for a forward shovel excavator; the scoop passes in succession through positions 1, 2, 2', 3 -- top of the face, 4 -- emptying of scoop. The basic dimensions of the forward shovel are: B -- maximum radius of ground cut; V -- maximum height of cut; G -- maximum unloading radius; D -- maximum height of unloading; and E -- maximum depth of scoop. For forward shovels of 0.25-0.50 cubic-meter scoop capacity, B equals 5.85-8-80 meters; V equals 5.0-6.42 meters; G equals 5.3-8.72 meters; D equals 3.4-4.71 meters; E equals 0.62-1.72 meters.

There are many operating plans for work performed by a forward-shovel excavator. The basic types of operating plans for use on rural hydroelectric power plant construction jobs are:

A. Working an excavation with bank dumping (Drawing 18) and fill dumping (Drawing 19).

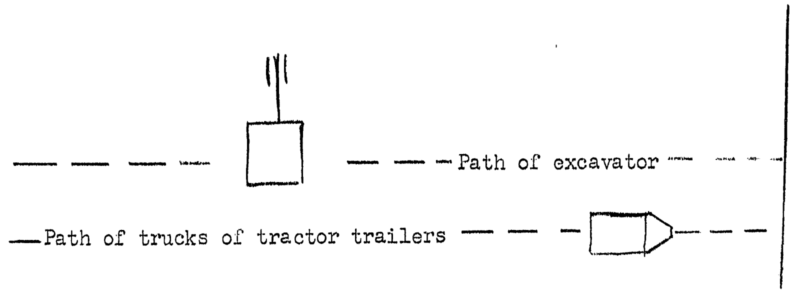


Drawing 18. Working a face by forward shovel with bank dumping.

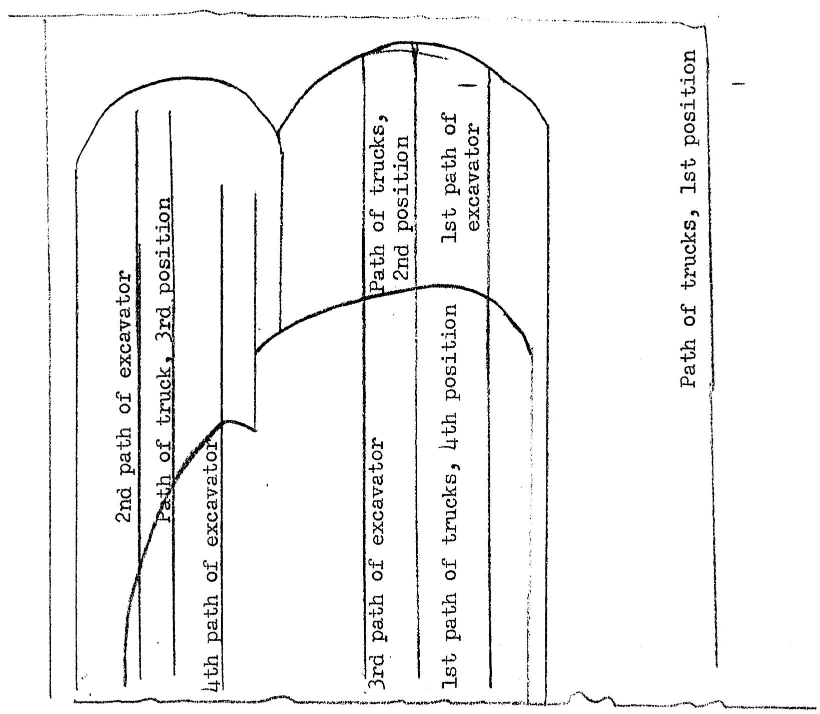


Drawing 19. Working a face by forward shovel with fill dumping

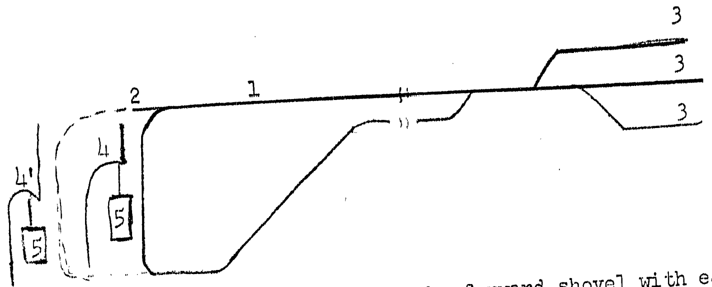
B. Working an excavation with dumping of earth into some sort of carrier (trucks or tractors with trailers, and railroad cars (Drawings 20,21, 22).



Drawing 20. Working a face by forward shovel with earth being dumped into trucks or tractor trailers.



Drawing 21. Working a face by forward shovel with earth dumped into trucks.



Drawing 22. Working a face by forward shovel with earth dumped into railroad cars. 1 - Loading track; 2 - extension of track to keep pace with excavation; 3 - unloading tracks; 4 - face; 5 - excavator.

OPERATING PLANS FOR WORK PERFORMED BY REVERSE SHOVELS

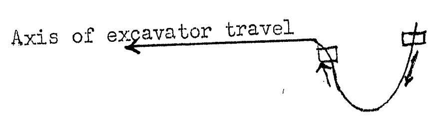
The reverse shovel differs from the forward shovel excavator in that while working it moves backwards rather than forwards. Because of this the machine moves not over the excavated cut, but over untouched ground, which makes its travelling much easier. If necessary, preliminary levelling and removing of any sort of obstacle in the path of the excavator must be done. The line of travel of the machine should afford uninterrupted working of the entire cross section of the excavation without ridges at the edge between the cuts of adjacent passes; these ridges result when the excavator is moved too far from the last pass. The normal distance to move between cuts is about half the depth of the cut.

Reverse shovels are used for digging foundation pits, trenches, and shallow canals. The work cycle of a reverse shovel is shown in Drawing 23.

Drawing 23. Work cycle of the reverse shovel.

In accomplishing its work cycle the scoop goes successively through: initial position over the ground to be cut - 1; radius of the cut - 2, 3; and dumping - 4. The basic measurements involved in the operation of a reverse shovel are: A - maximum height of dumping -- 2.15-3.3 meters; B -- maximum radius of dumping -- 2.4-5.8 meters; V -- maximum depth of excavation -- 3.5-6.6 meters; G -- maximum radius of excavation 7.5-10.8 meters. The operating plan for digging a canal using a reverse shovel is shown in Drawing 24; plan for digging a foundation pit is shown in Drawing 25.

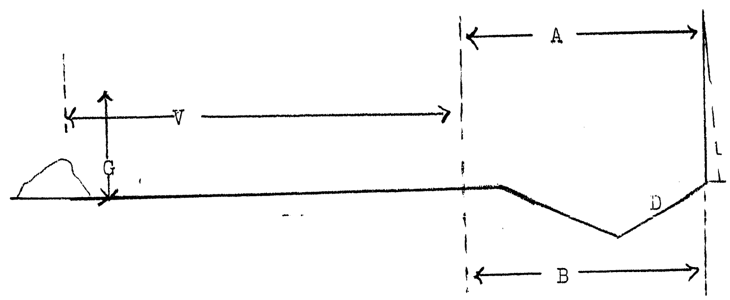
Drawing 24. Operating plan for digging a canal.



Drawing 25. Operating plan for digging a foundation pit with earth removal by truck.

DRAGLINE EXCAVATOR OPERATIONS

The following are the first things we notice in looking at the work diagram for this type of excavator: when operating, the excavator is located at the top of the cut and moves steadily backwards; the scoop tears the earth away in the direction of the excavator, the working gear of which has large radii of action; the free suspension of the scoop makes dumping of the earth into the carrier somewhat difficult, which is why this type of excavator is used preferably in dumping operations where earth need not be carried to the side



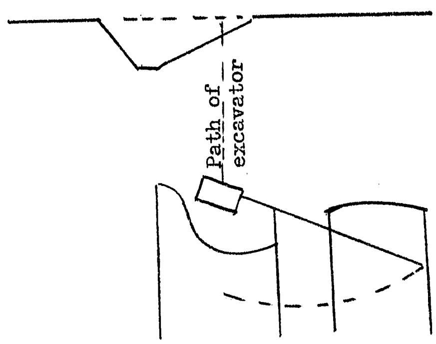
Drawing 26. Operating cycle of a dragline excavator

Inaccomplishing its working cycle, the scoop assumes the following positions: 1 -- beginning of cut; 1' -- same, after scoop throw; 2 -- end of cut; 3 -- full scoop in carrying position; 4 -- emptying of scoop. The basic measurements in dragline excavator operations using a 0.25-0.50 cubic-meter scoop are: overhang of boom A -- 5-12 meters; radius of excavation B -- 6.75-13.1 meters; V -- dumping radius -- 5.96-9.1 meters; G -- height of dumping -- 4.68-7.05 meters; maximum depth of excavation D -- up to 10 meters.

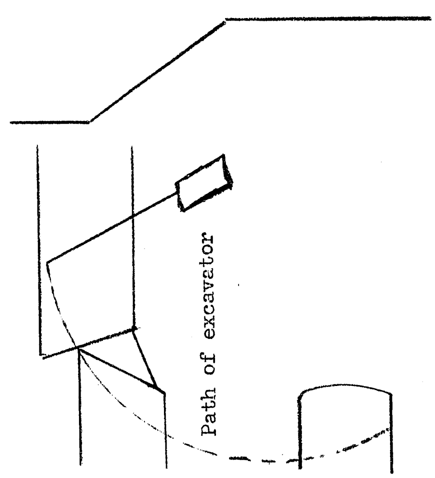
The main working plans for dragline excavator operations are:

(1) Front-on or longitudinal working of the cut (Drawing 27)

(2) Lateral or transverse working of the cut (Drawing 28)



Drawing 27. Working plan for Front-on or longitudinal working of a cut with a dragline excavator.



Drawing 28. Working plan for lateral or transverse working of a cut with a dragline excavator.

DETERMINING THE PRODUCTIVITY OF EXCAVATORS

The technical productivity of single-bucket excavators can be computed by the formula

$$P_t = 60\ nq\ K = m^3/\text{hour compact earth}$$

where n -- number of working cycles per minute

q -- bucket volume (in cubic meters)

K -- combined coefficient of bucket admission and breaking up of soil.

The vâlue of K for excavators carrying 1 cubic-meter buckets is: forward shovel -- 0.7-0.9; dragline excavator -- 0.75-0.85.

The working productivity of an excavator is determined by the formula $P_e = P_t\ K_v\ m^3$/hour of shift work, where K_v is the coefficient of machine utilization expressed in time.

The values of K_v differ somewhat depending on the time for which it is taken (shift, 24-hour day, month, year).

Variable K_v represents the relationship between the actual working time of the excavator during the shift and the length of the shift (8 hours). The discrepancy between the shift time and the actual time worked is accounted for by the movement of the excavator, fueling, lubricating, cleaning the cut, work stoppages connected with changing carriers for removing earth, etc.

The values of $K_{v\ sm}$ vary from 0.72 to 0.87 (the latter applying in terrace workings).

The daily coefficient of excavator utilization for the period $K_{v\ sut}$ further takes into account the number of work shifts performed by the excavator per 24-hour period. In one-shift operations $K_{v\ sut}$ equals 0.33 $K_{v\ sm}$; in two-shift operations 0.67 $K_{v\ sm}$; and in three-shift, $K_{v\ sut}$ equals $K_{v\ sm}$.

The monthly coefficient $K_{v\ mes}$ and the yearly $K_{v\ god}$ take into account excavator standstill time consumed in performing medium and capital repairs, transfer from one place of work to another, assembling and taking apart, as well as time lost as a result of atmospheric conditions (bad weather, low temperature,etc). The values of $K_{v\ mes}$ and $K_{v\ god}$ which indicate what part of the computed working time of the month or year is actual working time under three-shift operations are as follows:

Region of Operation	K_v month	K_v year
Northern	0.59	0.37
Central	0.59	0.44
Southern	0.61	0.46

MOVING EARTH IN EXCAVATOR OPERATIONS

The earth which is dug by excavators is either unloaded directly on a dumping pile within the limits of the operating radius of the machine, or into some sort of carrier which subsequently dumps the dirt on a bank or fill. The first method is called a dumping operation, and the second, a transport operation.

In the first case the operation of the excavator is not related to the work of the transport, which makes it possible to attain higher coefficients of machine time utilization than in transport operations. In dumping earth into a fill the operation of the excavator is complicated by the necessity of coordinating the removal of the earth with the operations of levelling, packing, and sometimes wetting down the earth in the fill. However, if a carefully planned schedule for the joint work of all types of equipment involved (excavator, bulldozer, roller, tank truck) is on hand, an adequately high coefficient of excavator utilization can be maintained.

Intermediate between the two types of excavator operation described (direct dumping and dumping into carrier) is the direct dumping method with subsequent removal of the earth to its ultimate depository either by reloading with the same excavators (rehandling operation) or by other means of transportation. With the exception of cases in which a bulldozer is being used to move the earth the necessary distance, in all other cases this method, as compared with the second method, increases the cost as a result of the need to reload the earth into a carrier, besides actually transporting the earth.

The removal of earth dug by the excavator can be performed with various means of transportation. These carriers together with the excavator comprise a single production complex in which the key machine is the excavator.

CARRIERS USED FOR EARTH REMOVED BY EXCAVATOR

When it is necessary to transfer earth over more or less great distances, narrow guage railroads, trucks, and tractors (with trailers) are ordinarily used. Below are given a few facts about these types of transport.

The main advantage of railroads is the low resistance to movement offered by the rails, thanks to which loads carried by this means require much less power to move than is required on railless roads.

Railroads are highly suitable for moving large quantities of earth over long distances at high speed. However, where it is not necessary to build expensive artificial structures along the route of the track and where a minimum amount of excavating has to be done (i.e., when the locality is of gentle contours), this form of transport can, even with small volumes over short distances, be more suitable than other methods of transport. In building rural hydroelectric power plants, narrow-guage (750 millimeter) railroads are used for the most part.

A railroad line consists of a lower and an upper structure. The first includes the bed and the artificial structures; the second comprises the rails, fishplates, ties, and ballast.

The roadbed serves as the foundation for the upper track structures.

The contour of the roadbed is determined by the longitudinal and transverse profiles.

These are the sections of the roadbed in a vertical plane relative to its longitudinal axis. A typical transverse profile of a railroad bed in an excavation is shown in Drawing 29.

Drawing 29. Typical transverse profile of a narrow-guage railroad bed in an excavation: 1 -- Rails; 2 -- ties; 3 -- ballast; 4 -- roadbed; 5 -- drainage ditch; 6 -- banket ditch; 7 -- bank.

Critical Grades and Radii of Curves

In building narrow-guage railroads the following maximum values for grade of track are used: with mechanical traction, 0.04 (in special cases up to 0.05); for working tracks, up to 0.06; with horse traction, up to 0.03; with hand traction up to 0.02. The correct selection of track grade magnitude is extremely important, since the grade determines the number of cars and their weight in the train.

The minimum permissible radii of curves in building a railroad of this type are the following: with mechanical traction, 50 meters, and under difficult topographical conditions, 30 meters (with steam locomotive traction) and 22 meters (with internal combustion locomotives); with horse and manual traction, 8-15 meters.

The smaller the magnitude of grade and the greater the radii of curves, the faster the movement of the train and the greater its weight; however, it is frequently necessary because of unfavorable terrain contours to increase the grade and shorten the radius of curves in order to avoid large cuts and fills, and hence cut down the productivity of the transport.

The optimum solution of these problems must be found for each individual case.

Upper Track Structures

The most important part of the upper track structure are the rails which receive the pressure of the wheels of the rolling stock directly and guide their movement. The rails rest on transverse beams -- the ties -- to which they are fastened by means of special nails called spikes. The individual rails are laid at their joints one to another with a certain amount of gap between the abutting ends of the rails and the joints are fastened with fish-plates, The ties are laid on the ballast, which is composed of a layer of sand, gravel, or hard rock rubble.

The pressure received by the rails is transferred to the ties, which in turn pass it on to the ballast which distributes this pressure equally over the roadbed.

The layer of ballast also cushions the shock of the wheels on the rails, keeps the rails from moving, and deflects the water that falls on the upper track structure.

Ties

Wooden ties made mainly of pine, spruce, oak, fir, larch and other woods are used for narrow gauge railroads. Metal ties are used for portable ties.

For laying one kilometer of narrow gauge track the following quantities of material are needed: rails by weight, 11-15 kilograms per running meter -- 22-30 tons; ties -- 1,440-1,600; fishplates -- 0.5 ton; backing -- 0.75 ton; spikes -- 1.05 tons; bolts -- 0.5 ton; switch crossovers -- depending on the track layout.

Portable Track

If it is frequently necessary to relay the tracks on a narrow-gauge railroad operation (as in open pit mining, excavating, etc.), then portable sections are employed consisting of two rails metal or wooden ties fastened to them. The individual sections are joined to each other by means of flat fishplates (Drawing 30) bolted over the abutting ends of the rails, or by hooks, which are used on tracks where manual or horse traction is being employed (Drawing 30).

Drawing 30. Fastening of rail sections with flat fishplates.

Drawing 31. Fastening rail sections by means of hooks.

Track Joints

At points where two tracks converge into one or where one branches in two switches are installed.

For switching the various units of rolling stock from one track to another at any angle of intersection between the tracks, turntables are used. Under construction conditions, turntables

Drawing 32. A mounted turntable.

Because of the temporary nature of railroad building for construction purposes, the artificial structures for them (bridges, conduits, supporting walls, etc.) should be built according to the lightest possible design and the cheaper materials than are used for railroads subject to regular traffic.

The rolling stock for railroads consists of flatcars, closed-side cars and locomotives. Flatcars and other types of cars are moved about by hand, horse, or mechanical traction. Among the most widely used types of cars are the so-called Koppelev [V-bottom hopper] cars with tilting body.

Drawing 33. Car with tilting body and triangular shape.

Locomotives are used for moving railroad trains; in the construction of hydroelectric power plants, internal combustion locomotives are generally used.

ELEMENTARY TRACTION COMPUTATIONS USED IN RAIL TRANSPORT

The maximum number of loaded cars in a train is determined (for a given locomotive power and for the track sector having the most unfavorable combination of grade and curve radius conditions) from the equation for the tractive force of the locomotive minus the sum of all the forces opposing movement, i.e., $F_o = W$, where

F_o represents the tractive force (expressed in kilograms) delivered by the locomotive (at a given speed) on the rim of the driving wheels (the so-called tangential tractive force), and W is the total resistance to the movement of the train in kilograms, comprising the resistance to the movement of the locomotive and the movement of the cars. In developed form:

$$W = P(W_o + W_i + W_r) + Q(W'_o + W_i + W_r),$$

where P -- weight of locomotive in operating condition (tons);

Q -- total weight of loaded cars in the train (tons);

W_o - the basic specific resistance of the locomotive on a straight horizontal section of track in kilograms per ton of locomotive weight; for narrow-gauge locomotives,

$$W_o = 4.85 + 0.001v^2$$

where v -- computed locomotive speed (km/hr);

W_i -- additional specific resistance to the rise in the track, equal to the number of thousands of this grade (in kg/tons). On descents, W_i has a negative value.

W_r -- additional specific resistance to track curvatures; for narrow-guage $W_r = \frac{500\,\ell}{R}$ kg/tons, where ℓ is the width of the gauge (in meters) and R is the radius of curvature (in meters);

W'_o -- basic specific resistance of all cars in the train in kilograms per ton of car weight loaded. For narrow-gauge cars W'_o = (5-10) kg/tons.

On the basis of the formulas adduced above, we obtain

$$Q = \frac{F_o - P(W_o + W_i + W_r)}{W'_o + W_i + W_r}$$

By this formula the computed car weight of the train is determined. The number of cars in the train n is computed by the formula

$$n = \frac{Q}{q}$$

where the magnitude of Q is obtained from the formula, and q is the weight of one loaded car (in tons); n is expressed as a whole number, its fractional part being disregarded.

The total weight of net load in train Q_1 is equal to the difference between the total weight of the loaded and empty cars nq and nq_1 (q_1 being the weight of the empty car), i.e., $Q_1 = nq - nq_1$ tons.

When internal combustion locomotive is used we can take the simpler formula:

$$Q' = \frac{F_k - P(W_i + W_r)}{W'_o + W_i + W_r} t.$$

In this case F_k (traction on the hook) represents the tractive force expended on the moving of the train of cars, and is the same as the force on the wheel rim (F_o) minus the magnitude of the basic resistance of the locomotive.

From the relationship existing between power of the locomotive engine N, its tractive force F, and the speed of movement v, expressed in the equation $N = \frac{Fv}{75\eta}$ (η = efficiency of the motor), it is evident that for a constant value of N, an increase in the value of F should result in a decrease in v, and vice versa; that is to say, depending on the given conditions of the transport operation we can increase the weight of the train while reducing its speed, or get greater speed by reducing the weight of the train, selecting from these two variants the more profitable.

Example

Quarrystone is being transported from a quarry to the construction site by narrow-gauge trains made up of flatcars pulled by an internal combustion locomotive built by the Kaluga Plant. It is necessary to determine the volume of stone carried by one train and the number of flatcars in the train.

Initial Data

The weight of the locomotive in operating condition is 8 tons, tractive force on the hook, 2,000 kilograms. Flatcars: weight (brakeless cars) 3.3 tons; brake cars, 3.7 tons; carrying capacity, 8.2 tons. Maximum grade of track in loaded direction, 0.20; maximum slope, 0.20; minimum radius of curvature, 75 meters; volumetric weight of stone to be hauled, 2,400 kg/cubic meter.

Solution

$$F_k = 2{,}000 \text{ kg}; \; P - 8t;$$

$$W_i = 20 \text{ kg/t}, \; W_r = \frac{500 \times 0.75}{75} = 5 \text{ kg/t}$$

Substituting in the formula for internal combustion locomotive we get:

$$Q' = \frac{2{,}000 - 8(20 + 5)}{5 + 20 + 5} = \frac{1{,}800}{30} = 60t.$$

For braking the train on slopes part of the flatcars should be equipped with brakes. The number of these depends on the maximum incline in the loaded direction and will be as follows for the degrees of slope shown, the number of braked cars being expressed in percent of the total number of flatcars in the train: 0.005 -- 8 percent; 0.010 -- 12 percent; 0.015 -- 17 percent; 0.020 -- 20 percent; 0.025 -- 30 percent; 0.030 -- 35 percent. In our example we have 20 percent brake cars and 80 percent brakeless cars. Then the average weight of a flatcar will be equal to 3,300 x 0.80 + + 3,700 x 0.20 = 2,640 + 740 = 3,380 kilograms, and the weight of a loaded flatcar is equal to 3,380 + 8,200 = 11,580 kilograms. The number of cars in the train will be equal to $\frac{60{,}000}{11{,}580} = 5$ cars. The volume of stone carried by one train is equal to

$$\frac{8{,}200 \times 5}{2400} = 17 \text{ cubic meters}$$

TRUCK TRANSPORT

According to design and function, trucks are divided into (a) general, and (b) special. General-purpose trucks are used for any ordinary loads, while special trucks are used for transporting specific types of loads to which certain types of trucks are suited (truck trailers, timber carriers, etc.).

The following are the special-type trucks used on construction jobs for carrying loose loads: metal-body trucks for carrying liquid and plastic construction materials (concrete, asphalt, etc.) dual-slope inclined floor trucks adapted from general-purpose trucks, permitting quick unloading of the materials hauled (sand, gravel, rubble, etc.), and dump trucks, which have tilting bodies (Drawing 34).

Drawing 34. Special types of trucks.
a. -- dual-slope inclined floor; b. -- dump truck

The best trucks are the dump trucks specially produced by the automobile industry.

Carrying all sorts of long loads (beams, boards, pipe, reinforcing iron, etc.) is done with general-purpose trucks equipped with one-axle trailers. Two-axle trailer trucks are also used to increase the carrying capacity of the truck.

Tractors

At present only caterpillar tractors are used in hydro-engineering construction. They are characterized by good road qualities and maneuverability.

Until recently, special construction tractors were not used in the Soviet construction industry; agricultural tractors of inadequate power and speed were the rule. Only recently has the 92-horsepower S-80 tractor started to come off the production lines. This model has a maximum speed of 9.65 kilometers per hour. However, not even this tractor can fully satisfy the needs which arise in construction work for more powerful and faster types of tractors. Such tractors especially designed to meet hydro-engineering construction demands are scheduled for production by Soviet industry in the next few years.

ELEMENTARY TRACTION COMPUTATIONS FOR RAILLESS TRANSPORT

Let us limit our examination to those traction computations needed in tractor trailer operations.

To determine the maximum net load weight to be hauled by the trailers of a tractor train and the number of trains, the total weight of the loaded trailers is first determined by the modified formula:

$$Q'' = \frac{F_k - P(W_i + W_u)}{W'_o + W_i + W_u} \ t$$

where F_k -- tractive force at the tractor hook (in kilograms)

P -- weight of the tractor (in tons)

W_i -- additional specific resistance to the grade, in thousandths of the latter (in kilograms/ton)

W_u -- additional specific resistance when starting the tractor, taken as 30-40 kilograms per ton;

W'_o -- specific resistance to movement of the trailers on a straight horizontal section of track; values for W'_o are shown in Table 6.

TABLE 6

The Values of W_0'

Type of Road	Truck	Tractor trailer Caterpillar Wheeled
Cobblestone road in good condition	40	40/50
Dirt road in good condition	80	100/80
Same, in poor condition	150	140/100
Rolled snow	30	30/30
No road -- hard earth	200	200/100
No road -- soft earth, fresh fill	300	300/100

Having determined the magnitude of Q'', the number of trailers in the train is found by dividing Q'' into the weight of one loaded trailer; and then into the maximum load to be carried by the tractor train, which is obtained by subtracting from the product of the weight of one loaded trailer and the number of trailers the total empty weight of the found number of trailers.

Comparative Evaluation of Truck and Tractor Transport in Construction

The main advantage of truck transport is speed; but for normal operation of truck transport, adequately good roads are necessary, a condition which is not always possible on construction jobs. When selecting the carrying capacity of trucks for a construction job it is essential that one try to limit the number of types of trucks, decide on the most suitable single main type for the given conditions, the selection of this type being dictated by the condition of the roads, the make-up of the loads to be carried (earth and other construction materials, mechanical equipment, etc.), the amount of load turnover and the length of the runs. The better the roads, the larger the load turnover, and the shorter the runs, the more advantageous large trucks become, and conversely.

The advantages of using tractors (caterpillar) lie in the possibility of movement without roads or on poor roads, the high tractive force, adaptability to making short turns and navigating broken terrain, and the possibility of using them for packing earth in making fills. The disadvantage of using tractors in Soviet construction work is their low speed. It is the job of the operations planner and the technical management of the construction project to provide a pool of trucks and tractors such that each type of transport operation is performed by the type of transport equipment most suited to the particular job.

TRAILER SCRAPER OPERATIONS

The field of application for scrapers is extremely broad -- including excavating and fill jobs, levelling operations, etc. -- in all cases where besides digging up earth it is necessary to carry it to one side.

Drawing 35 shows the D-183 tractor scraper with scoop capacity of 2.25 cubic meters. Drawing 36 illustrates the horse-drawn shovel scraper with 0.1-cubic-meter scoop.

Beginning of lowering

Full cutting depth

Drawing 35. D-183 tractor scraper with 2.25-cubic-meter scoop.

Drawing 36. Horse-drawn shovel scraper with 0.1-cubic-meter scoop.

It is difficult to use scrapers in rainy periods when working clayey and loamy soils; movement over such soil is difficult because the earth sticks to the walls of the scraper sccop and the wheels of the scraper and the treads of the caterpillar tractor slip.

In actual operation, the scraper is in continuous forward motion; all the elements of each working operation are accomplished with the scraper in motion, without stopping, although at various speeds, depending on the amount of resistance being overcome by the scraper at any particular moment in operation.

The paths of travel described by scrapers in each working operation are usually closed curves (ellipses, figure-eights, etc.), the form and size of which are determined by the relative position of the spot to be worked and the dumping ground for the earth.

Tractors used in other fields of the national economy, particularly the STZ-NATI, the S-80, etc., are employed for trailer scraper operations.

The digging and collecting of earth by scraper is done in successive layers, the thickness of which depends on the depth to which the blade of the scraper is lowered into the ground (from 100 to 300 millimeters for various types of scrapers); the width of the cut is equal to the length of the scraper blade. In gang scraper operations the length of the strip worked is determined by getting the total volume of the scoops of all the scrapers in the gang.

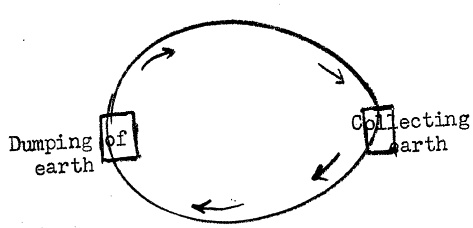
The actual scraping of the earth (and its consequent collec-ion in the scoop) must be done in a straight line (to avoid in-creasing the tractive force with a curvilinear path).

In scraping moist soils (heavy loam, clay, etc.) the ground must first be broken up with plows or spike rollers. Coordination of the earth loosening and scraping are extremely important in avoiding stops in the operation of the equipment. Since both operations are done in layers each process must be done in turn. To make this possible the section of ground to be scraped must be of such dimensions that the plowing of each half of the digging will provide that amount of broken ground corresponding to the day or shift capacity of a given number of scrapers. With each successive time unit the equipment for breaking up the soil and scraping it change places. This working in turn continues until a given section of the excavation is completed. The depth of the plowing should be equal to or less than the depth of ground cut by the scoop of the scraper. The productivity of a given number of plows or spike rollers (per sector of the operation) should be equal.

The dumping of earth from scrapers is done in layers; the filling in of each layer begins from the base of the slope and proceeds toward the center of the fill. The levelling of the dumped earth is either performed by the scraper itself or by levelling machines -- graders, bulldozers, etc.

When high-grade fills are being put in the dumping should be accompanied with packing and wetting-down operations.

The movement of the loaded scrapers from the cut to the point where the earth is to be dumped (and back to the cut) can be accomplished according to a number of work plans. In selecting the plan for scraper travel one should be guided by the following considerations: (a) the length of the haul from the cut to the dumping point should be as short as possible; (b) the natural slope of the locality should be exploited for the loaded part of the hal; (c) the movement of the scrapers over broken terrain should be kept to a minimum; (d) the paths of movement of the scrapers should have the least possible number of turns; (e) the paths of movement of the scrapers should all be in one and the same direction; hauling one scraper across the path of another should not be permitted.



Drawing 37. An elliptical plan for moving tractor scrapers.

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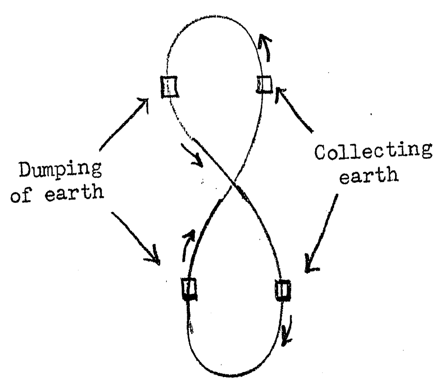
Movement according to an elliptical plan (Drawing 37) is the most widely used method, particularly where the depth of scraping is not great and the height of the fills low (say, 1-1.5 meters). In this case the ascent of the tractor with its scraper can be made right on the slope of the cut and fill. Where large cuts and fills are being made, special ramps and approaches for the scrapers have to be built (Drawing 38); this makes additional work which increases the total amount of work and raises the unit cost of moving the earth.

Drawing 38. Ramps and approaches for scrapers.

In many cases the figure-eight is used as the scraper path of travel (Drawing 39).

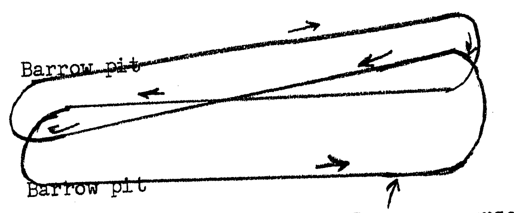


Drawing 39. Tractor scraper movement on the figure-eight plan.

In this work plan the line of loaded travel from the collection point lies at various angles to the horizontal axis of the excavation, ranging from 30 to 90 degrees. The longer the loaded haul, the smaller this angle. At the limiting angle of 90 degrees the figure eight turns into two ellipses, with the minimum loaded travel distance being equal to the perimeter of the ellipse.

Drawing 40 shows a layout for working barrow pits located at the beginning of the fill; Drawing 41 shows a layout for the longitudinal removing of earth, a method used when linear structures are being put up using earth from a digging-in-progress for the fill.

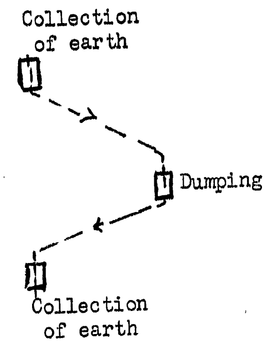
In working linear structures, particularly when alternating fill and cut (as, for instance, in building a roadbed), it is often a good idea to use a "snake"-shaped course (Drawing 42).



Drawing 40. Layout for working barrow pits by scraper, the pits lying at the beginning of the fill.

1 - Collection of earth; 2 - dumping

Drawing 41. Layout for longitudinal removal of earth by scraper from cut to fill.



Drawing 42. "Snake"-shaped course for tractor-scraper movement.

The main feature of this method (Drawing 42) is that instead of describing closed curves, the scraper moves through a sine curve of great length, first in one and then in the opposite direction, each pass being made up of a number of working cycles, the length of which is greatly reduced by cutting down on the empty runs.

To assure the maximum efficiency of scraper operations a number of rules must be observed, among which are the following:

1. The tractor driver should try to work at the maximum possible speed for each moment of the operation in keeping with the tractor's capacity, and to cut down as much as possible on the length of the course travelled.

2. The blade of the scraper should be lowered to the greatest possible depth for a given soil and maximum use made of the power of the tractor; the scoop of the scraper should be as full as possible (working with a full cap ["shapkoy"]).

3. The paths followed by the scraper rigs should be kept in good condition; a grader or bulldozer should be specially assigned to continually level the scraper runs.

4. In working with gang scrapers the number of scrapers in the gang should be as great as possible; the scraping and dumping strips should be sufficiently long to assure complete collection and discharge of earth; movement of the gang along ramps and inclines should always be in a straight line coincident with the longitudinal axis of the ramp or incline; where hauls of considerable distance are being made (over 200 meters) and when simultaneous operation of several gangs is going on, only the tractor driver should go with the haul; workers at the collection and dumping points are assigned to handle the loading and unloading of all the operative gangs in succession.

5. The operation should be carried out only according to a previously worked out plan of organization of scraper jobs; the plan should contain all necessary data, particularly detailed plans on how the work is to be done, layouts for the movement of scrapers, locations of ramps and inclines at the cut and the dumping point, schedules for the combined operation of scrapers and other machines (earth breakers, rollers, etc.).

Determining the Productivity of Tractor Scrapers

The productivity of tractor-drawn scrapers is determined according to formula:

$$P_{ekspl} = nn_1 qK_r K_n K_v \text{ cubic meters/hour of shift operation}$$

where n -- number of working cycles per hour

n_1 -- number of scrapers in the gang

q -- geometric volume of the scoop (in cubic meters)

K_r -- coefficient of mellowing

K_n -- coefficient of scoop filling

K_v -- coefficient of time utilization

The number of working cycles per hour $n = \frac{60}{T}$ where T is the duration of one cycle (in minutes),

In turn,

$$T = t_1 + t_2 + t_3 + t_4 =$$

$$= \frac{\ell_1}{v_1} + \frac{\ell_2}{v_2} + \frac{\ell_3}{v_3} + \frac{\ell_4}{v_4},$$

where $t_1 = \frac{\ell_1}{v_1}$ -- the length of time required to fill the bucket when ℓ_1 is the length of the scraping strip and v_1 is the speed of the gang during the scraping (in meters per minute);

$t_2 = \frac{\ell_2}{v_2}$ -- the duration of the loaded haul (in minutes) where ℓ_1 is the length of the loaded haul (in meters) and v_2 is the loaded speed of the gang (in meters per minute);

$t_3 = \frac{\ell_3}{v_3}$ -- the duration of the dumping process, where ℓ_2 is the length of the dumping run and v_3 is the speed of the gang while actually dumping;

$t_4 = \frac{l_4}{v_4}$ -- duration of the empty run, where l_4 is the length of the run and v_4 the speed of the empty run.

In determining the magnitudes l_1, l_2, l_3 and l_4, we take the mean actual distances of the run, taking into account the vertical ascents.

Hence, as developed from the formula it appears as follows:

$$P_{ekspl} = \frac{60\, n_1 q K_p K_n K_v}{\frac{l_1}{v_1} + \frac{l_2}{v_2} + \frac{l_3}{v_3} + \frac{l_4}{v_4}} .$$

The number of scrapers in the gang n_1 varies from one to six. The coefficient of soil mellowing K_r is: 0.88-0.90 for dry soil; 0.84-0.88 for soils of the I and II categories (besides sand); and 0.71-0.73 for soils of the III and IV categories.

The values of the coefficient of scoop-filling K_n for various types of scrapers range from 0.71-1.2 (magnitudes greater than 1.0 apply when the scraper is filled to more than capacity [shapkoy]).

The coefficient of time utilization is taken as equal to 0.85-0.90; l_1 and l_3 for various scraper models have different values; for the STZ-3NATI, l_1 = 22 meters; l_3 = 10 meters.

The lengths of the full and empty runs l_2 and l_4 are taken as equal to the actual length of these runs in each case. The values of v_1, v_2, v_3, v_4 are determined by the speeds of the tractors. v_1 is the first-gear speed, v_2 and v_3 the second and third speeds, and v_4 is the third-fifth speeds.

Of the two formulas given above for the productivity of scraper operations, the first is used for approximate computations of productivity where a certain number of working cycles per hour is known; for more exact computations the second formula is used, for which it is necessary to know the magnitude of all the elements of the work cycle (speed, length of hauls, etc.).

Scraper operations can be performed not only with tractors but with horse traction as well. Because of the growth in mechanization of excavation, particularly in the broad introduction of tractor scrapers, the importance of horse-drawn scrapers has been greatly reduced; at present their use is limited to small-volume excavation jobs and various types of finishing and auxiliary operations.

Horse-drawn scrapers are used on construction jobs being carried out by kolkhozes (particularly on the construction of kolkhoz hydroelectric plants) when the horse pool is not being used for other work. While the productivity of horse-drawn scrapers is considerably lower than that of tractor scrapers, horse-drawn scrapers are, on the other hand, one of the most effective and economic means of performing nonmechanized excavation (where the earth must be moved to one side).

Types of Horse-Drawn Scrapers

Two types of horse-drawn scrapers are presently in use: (a) the draw-scraper [skreper-volokusha] and the scraper on runners.

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Horse-drawn scrapers, like tractor scrapers, scrape the ground in separate working cycles. The worker who drives the horse-drawn scraper guides the horse and the scraper scoop simultaneously. The scrapers operate on the bucket-line principle in squads, with several scrapers in each squad. The following are the recommended number of scrapers in a squad relative to the distance of the haul:

Distance (in meters)	15	20	30	40	50	60	80
Number of scrapers in the squad	3	3	4	5	7	8	8

The number of scrapers in the squad for a given haul distance is defined by the necessity of maintaining such intervals between scrapers as will permit the rest of the scrapers to keep moving when one of them has to stop.

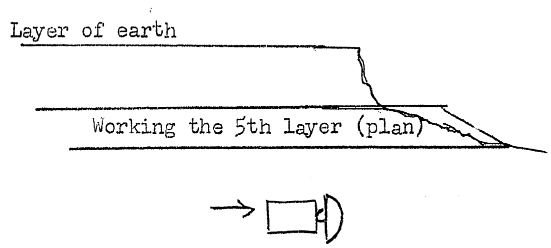
PERFORMING AUXILIARY OPERATIONS IN EXCAVATION (MECHANIZED)

Levelling of earth is done in many cases -- putting in fills, packing banks and other dumpings into proper shape, levelling construction sites, etc. The basic machine for performing this type of work is the bulldozer, which recently has come into wider and wider use. Graders (primarily in road construction) and scrapers are also used.

The bulldozer has a wide variety of uses -- moving and smoothing down levelling of sites, filling in holes and foundation pits, clearing sites of wood and scrub growth, removing earth from diggings, building ramps, clearing snow, etc. The bulldozer is used in conjunction with other machines or as an independent piece of equipment (in levelling operations, moving earth, etc.).

Stripping up ground by bulldozer (as with scraper) is done in layers with various depths of blade (averaging 100-200 millimeters). As the bulldozer moves forward it accumulates a wedge of earth in front of its moldboard (3-5 cubic meters in volume) which the machine pushes along in the direction of its travel. Heavy earths (categories III-IV) should be broken up before dozing.

For success of the operation the loaded trip should be on a slight incline.



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Drawing 43. Working plan for moving earth into a bank by bulldozer.

Spreading earth on a fill is done by bulldozers with the moldboard set at an angle to the longitudinal axis of the machine;

the earth brought for the fill is stores in a row of piles parallel to the longitudinal axis of the fill running from shoulder to center. Drawing 44 shows a working plan for levelling each layer of a fill.

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Drawing 44. Working plan for levelling a fill in layers by bulldozer.

With this method the bulldozer makes no idle runs. When a bulldozer moves earth, part of the earth which runs off each end of the moldboard is lost. This loss can be greatly reduced by using two bulldozers at once, operating with their moldboards in line. In this method the productivity of the bulldozer is increased an average of 15-20 percent because of the reduced loss of earth.

Filling a trench with earth (after laying of pipe, conduit, etc.) is done by bulldozer according to various work plans. An example of this is illustrated in Drawing 45.

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Drawing 45. Work plan used for filling in a trench by bulldozer.

The bulldozer can also be used for joint operations with excavators and other earth-moving machinery where additional movement of loosened earth is necessary.

Putting on and removing bulldozer gear from a tractor is simple and takes little time. In mounting, the frame rests on the ground and the tractor moves into the yoke of the frame which is then fastened to the tractor.

The productivity of a bulldozer is computed in the following manner:

(a) In digging up and moving earth the following formula is employed:

$$P_{ekspl} = \frac{60qK_v}{T} = \frac{60qK_v}{t_1 + t_2 + t_3 + t_4 + t_5} \text{ m}^3\text{/hour}$$

of shift operation

where

P_{ekspl} -- productivity of the bulldozer per hour of shift operation;

q -- volume of earth, compact, dug and moved in one pass;

K_v -- coefficient of bulldozer time utilization, usually taken as 0.85-0.90;

T -- duration of one trip of the machine;

$t_1 = \frac{l_1}{v_1}$ -- duration of cutting over course l_1 at bulldozer speed v_1 meters per second;

$t_2 = \frac{l_2}{v_2}$ -- duration of moving earth over course l_2 at bulldozer speed v_2 meters per second;

$t_3 = \frac{l_1 + l_2}{v_3}$ -- duration of the return run of the bulldozer at speed v_3 meters per second;

t_4 -- time required to shift gears 0.1 minute;

t_5 -- time spent on turning bulldozer, taken as an average of 1/2 minute. When the distance the earth has to be moved is less than 30 meters, the bulldozer makes the return trip in reverse ($t_5 = 0$).

(b) In moving earth which has previously been loosened, $t_1 = 0$ and $t_3 = \frac{l_2}{v_3}$; the formula assumes the form:

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$$P_{ekspl} = \frac{60qK_v}{t_2 + \frac{l_2}{v_3} + t_4 + t_5}$$

(c) In levelling earth where the earth is moved lengthwise along the blade of the moldboard, the formula expressing the productivity of the bulldozer in square meters of area levelled per hour of shift work is:

$$P_{2\ ekspl} = \frac{60\,l(b\ \cos\alpha - 0.30)K_v}{\left(\frac{l}{v_2} + t_3\right)n}$$

where l -- length of one pass of the bulldozer (in meters);

b -- length of blade (in meters);

α -- angle between the blade and the perpendicular to the direction of travel of the machine;

0.30 -- width of overlap between two adjacent passes of the bulldozer;

n -- number of passes of the bulldozer over a single site; v_2 and t_3 have the values previously assigned for working unloosened earth.

PACKING EARTH

Packing Earth by Roller

The working element of a roller is a heavy drum of cyclindrical shape, the lateral faces of which roll down in strips the earth to be packed, this packing is effected by the weight of the high specific pressure of the drum on the earth (up to 70 kilograms per square centimeter).

Roller drums are made hollow; to increase their weight they are filled with water or wet sand. Several drums can be towed by one tractor. Tractors are used for traction. [Sic!]

The productivity of rollers is computed according to the following formulas:

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$$P_1 = \frac{(b-0.2)vK_p\ K_v}{n}\ m^2\ /\text{hr of shift work}$$

$$P_2 = \frac{(b-0.2)vhK_p\ K_v}{n}\ m^3\ /\text{hr of shift work}$$

In these formulas:

b -- length of the roller drum (in meters); where several rollers are in tow, b is the width of the strip covered in one pass (in meters);

0.2 meters -- width of overlap of adjacent strips rolled;

v -- speed of towing tractor; 2nd gear is usually used; n is the number of passes of the roller over one site, equal to approximately 6-11;

h -- thickness of the packed layer, taken as 15-20 centimeters for smooth rollers and 20-35 centimeters for fluted rollers.

K_v -- coefficient of time utilization; K_p is the coefficient of time lost in turning; depending on the length of the pass this varies from 0.8-0.95.

Packing Earth by Other Types of Equipment

Packing of earth by means of static force applied to it can, besides with rollers, be performed in passing by the rolling surfaces of various types of transport machinery and several construction machines (trailer scrapers, etc.). By this method the ground attains considerable compactness; where scraper gangs are used the earth is compressed up to 97 percent of the compactness of its natural state; with horse-drawn transport, 87 percent; with truck [tachechnyy] transport, 89 percent. However, to obtain a high-grade fill the necessary compactness can only be achieved with special packing equipment (fluted rollers, mechanical tampers, etc.); this fact does not eliminate the use of the above-mentioned means of transport for rolling purposes (scrapers, etc.) but only limits them to auxiliary measures.

The packing of soil by means of dynamic force exerted on it is accomplished with tampers, tamping plates, and tamping machines. The ground is packed by means of successive blows delivered by the working element of this equipment.

Packing of loose soil can also be successfully accomplished by surface or internal vibrators.

In selecting the type of mechanical equipment for packing earth, the following should be kept in mind:

1. Of the various types of rollers first preference should be given to fluted rollers; smooth rollers can be used

for final packing of the top layer of the fill and for work in conjunction with fluted rollers.

2. Machines which act dynamically on the earth (tampers and plates), as well as vibrators (only to be used with loose earth), are efficient to use where it is possible to put in the fill in thick layers, or where the operation is in a limited area.

3. Very loose dirt dumped by truck, grader-elevator, etc., should first be packed with light rollers and then by heavy.

Collated data on the thickness of packed layers of earth and the number of passes are shown in Table 7.

TABLE 7

COLLATED DATA ON THICKNESS OF ROLLED LAYERS AND NUMBER OF PASSES

Type of Equipment	Thickness of the layer being packed, Loose, (in centimeters)	Number of Passes (or blows) Needed on a Given Point: Loose Earth	Compact Earth
S-65 tractor with trailer scraper	15-20	8-12	12-16
Smooth trailer roller, (3-ton)	10-15	6-9	9-15
Heavy self-propelled roller	20-30	4-6	8-12
Fluted roller	20-30	4-6	8-12

E N D